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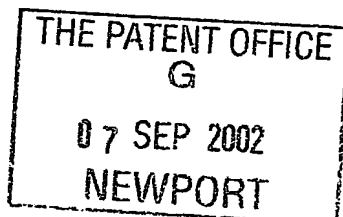COMPLIANCE WITH RULE 17.1(a) OR (b)

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l.	Your reference	P31080/JED/JDB

2.	Patent Application Number *(the Patent Office will fill in this part)*	**0220838.7**	'07 SEP 2002

3.	Full name, address and postcode of the or of each applicant *(underline all surnames)*	Robert Gordon University Schoolhill Aberdeen AB10 1FR
	Patents ADP number *(if you know it)*	6310098003
	If the applicant is a corporate body, give the country/state of its incorporation	United Kingdom

4.	Title of the invention	"Screen System"

5.	Name of your agent *(if you have one)*	Murgitroyd & Company
	"Address for service" in the United Kingdom to which all correspondence should be sent *(including the postcode)*	165 - 169 Scotland Street Glasgow G5 8PL
	Patents ADP number *(if you know it)*	1198015

		Country	Priority application number *(if you know it)*	Date of filing *(day / month / year)*
6.	If you are declaring priority from one or more earlier patent applications, give the country and the date of filing of the or of each of these earlier applications and *(if you know it)* the or each application number			

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I/We request the grant of a patent on the basis of this application

Signature *MURGITROYD & COMPANY*   Date 06/09/2002

MURGITROYD & COMPANY

12. Name and daytime telephone number of
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James D Brown   01224 706616

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1 **"Screen System"**

2

3 This invention relates to a screen and in particular

4 a screen for use in oil and gas wells.

5

6 More than 80% of oil and gas clastic reservoirs

7 world-wide are known to be in various stages of

8 unconsolidation which may potentially cause the

9 reservoir to produce sand. This is especially true

10 for reservoirs located in deep waters. Similarly,

11 many of the reservoirs in mature fields are in an

12 advanced state of depressurisation, which makes them

13 susceptible to sand failure. Consequently, at

14 various stages in the economic life of a field, a

15 reservoir located therein will generally require

16 some form of sand control completion. To this end,

17 there is currently an increasing trend towards the

18 use of different screen systems (either barefoot in

19 openhole completions or gravelpack screens) in the

20 completion of wells drilled through reservoirs with

21 sanding problems.

22

1 In an attempt to improve oil or gas recovery at
2 minimal cost from marginal and mature fields,
3 horizontal, extended reach and multilateral wells
4 are becoming the most popular advanced wells for
5 optimal field developments, especially in
6 challenging deep water High Pressure/High
7 Temperature (HP/HT) environments like the Atlantic
8 margin. Sand control in these wells with screen
9 systems (with or without gravelpack), involves
10 placing the selected screen in the well bore within
11 a pay region specifically designed to allow
12 reservoir fluids to flow through the screen slots
13 whilst enabling the screen to filter out formation
14 sand grains. A key part of the screen design
15 therefore is the screen slot gauge, wherein this
16 parameter is estimated by way of the formation grain
17 size distribution. However, any solids loading or
18 sand migration through the slots may lead to
19 plugging and screen erosion with attendant downhole
20 problems including sand production.
21
22 A variety of different generic screen systems are
23 currently in use in the oil industry, such as simple
24 slotted liners, wire wrapped and pre-packed screens,
25 excluder, equalising and conslot screens and special
26 strata pack membrane screens. These screens
27 characteristically have symmetric, fixed geometry
28 slots. However, when these screens are used in
29 advanced wells, the screens are subjected to a non-
30 uniform particulate plugging profile which results
31 in "hotspots" developing in the screen; this is a
32 major concern because it causes erosion of the

1 screen resulting in massive sand production.

2 Follow-up workover operations of such screens are

3 limited to in situ acid washes or vibration or

4 insertion of a secondary slim screen (such as

5 stratacoil) into the damaged screen, which has an

6 adverse affect on reservoir inflow and well

7 performance. Also, retrieval of damaged screens

8 from specially extended-reach wells is almost

9 impossible. Consequently, in adverse conditions,

10 some wells have been abandoned and expensive side-

11 tracks drilled.

12

13 The main difference between the various screen

14 systems currently in use resides in the geometry or

15 configuration of the rigid screen shroud with its

16 fixed, symmetric slots. These systems have

17 different degrees of susceptibility to plugging and

18 operations engineers are usually left with the

19 problem of selecting the most appropriate screen

20 systems to use for specific sand control completions

21 from the range of screen systems currently

22 available.

23

24 Previous work by investigators has shown that the

25 stability and bridging effectiveness of typical

26 filtration media such as screen systems or

27 gravelpacks are functions of operational,

28 environmental and geometric parameters which are

29 largely dependant on the following:

30   •   Formation grain sized distribution and

31   sorting;

1 • Type of reservoir fluids and fluid
2 properties;
3 • Reservoir drawdown and production; and
4 • The geometry of the filtration medium.
5

6 Thus for a defined operating and production rate and
7 drawdown condition, a clastic unconsolidated
8 reservoir will produce sand grains of a particular
9 size distribution which is dependant on the
10 reservoir characteristics. Thus the amount and size
11 distribution of solids contained in a given barrel
12 of fluid produced from an oil or gas well, depends
13 on the bridging effectiveness of the filtration
14 media used in the wells, wherein the bridging
15 effectiveness can be evaluated for defined
16 operational conditions.
17

18 According to the invention there is provided a
19 screen system for underground wells, the screen
20 system comprising a screen;
21 wherein the screen comprises a plurality of slots;
22 and
23 a mechanism capable of varying the size of the said
24 slots.
25

26 According to the invention there is provided a
27 method of fluid flow control and/or sand production
28 control in a well, the method comprising the steps
29 of placing a screen having a plurality of slots in
30 the well and varying the size of the slots.
31

1 Preferably, the screen system comprises a pair of

2 screens comprising a slotted inner screen disposed

3 within a slotted outer screen. Optionally, at least

4 one screen shroud is further provided which is

5 attachable to the outer screen.

6

7 Typically, the inner screen is rotatable relative to

8 the outer screen. Preferably, the inner screen

9 comprises a substantially cylindrical member having

10 a pair of ends wherein one end is rotatable relative

11 to the other end by operation of the said mechanism.

12 Typically, the mechanism comprises a motorised

13 actuator.

14

15 Preferably, the screen comprises a plurality of

16 longitudinally arranged members and at least one

17 transversely arranged member which combine to

18 provide the slots in the interstices therebetween,

19 wherein, rotation of one end of the screen causes an

20 end of the longitudinally arranged members to rotate

21 relative to the other end of the longitudinally

22 arranged members such that the slot size is capable

23 of being varied.

24

25 Preferably at least one screen shroud is provided

26 with electromechanical sensors.

27

28 Preferably, the inner screen is rotated under the

29 control of a controller which is further connected

30 to the electromechanical sensors.

31

1 Preferably the controller employs a solids

2 prediction model to calculate a control action.

3

4 Preferably the controller further employs a plugging

5 tendency model to calculate a control action.

6

7 According to a second aspect of the invention, the

8 screen system is further provided with an external

9 screen shroud.

10

11 Preferably, the external screen shroud is

12 perforated.

13

14 Embodiments of the present invention will be

15 described by way of example only, with reference to

16 the accompanying drawings, in which;

17   Figure 1a is a side elevation of a bottom

18   section of the screen system, in accordance

19   with the present invention, highlighting a

20   protective shroud, an inner screen and base of

21   the screen, without showing an outer screen;

22   Figure 1b is a side elevation of an upper

23   section of the screen of Figure 1a,

24   highlighting the outer and inner screen without

25   showing the protective shroud;

26   Figure 2 is a block diagram of an architecture

27   for a system for controlling the slot angle of

28   the screen system of Figures 1a and 1b; and

29   Figure 3 is a flow chart showing the different

30   stages in the process of controlling the slot

31   angle of the screen system of Figures 1a and

32   1b.

1   Referring to Figure 1a, a screen system 5 is shown

2   for use in underground wells such as oil and gas

3   wells (not shown), and is provided with an optional

4   external protective shroud 10 substantially

5   comprised of a high grade steel perforated pipe.

6   The external protective shroud 10 acts as a blast

7   protector and helps support any unconsolidated

8   reservoir sand collapse around the screen system 5.

9   The external protective shroud 10 is provided with a

10   high density of perforations of large diameter, this

11   feature minimises the development of any potential

12   hotspots in the screen and provides a maximum area

13   for fluids to flow through.

14

15   In a second embodiment of the invention, the screen

16   system 5 does not require an outer protective shroud

17   10 and is used with a drill-in Liner (DIL) pre-

18   installed within the well.

19

20   Referring to Figure 1b, the shroud 10 (not shown in

21   Figure 1b) encases two concentric slotted screens 12

22   and 14, namely a rigid outer screen 12 and an inner

23   screen 14 wherein the inner screen 14 is

24   telescopically moveable relative to the outer screen

25   12.

26

27   A first end 16, in use upper end 16, of the outer

28   screen 12 is provided with an aperture (not shown)

29   through which a quick connect joint 18 extends. The

30   quick connect joint 18 is sufficiently wide to fill

31   the aperture.

32

1 A first end 19 of the inner screen 14 is provided

2 with a rigid drive shaft 20 which is latchable onto

3 a first end (not shown), in use lower end, of the

4 quick connect joint 18. A second end 22 of the

5 quick connect joint 18 is connectable to a hydraulic

6 motordrive shaft (not shown) or electrohydraulic or

7 electromagnetic actuator via a second quick connect

8 joint to actuate or turn the upper end 19 of the

9 inner screen 14 to a specified angle.

10

11 The quick connect joints at each end of the outer

12 screen 12 have bearings that permit rotation of the

13 inner screen 14. The inner screen 14 is driven by

14 means of the drive shaft 20 at the upper end of the

15 outer screen 12, which is urged by the

16 electromagnetic/electrohydraulic actuator.

17

18 A swivel base 24 is welded to a second end (not

19 shown), in use lower end, of the inner screen 14. A

20 first end 26, in use upper end 26, of the base

21 swivel 24 is attachable eg via a latch (not shown)

22 to a second end 28, in use lower end 28, of the

23 outer screen 12 to allow for minimal torque rotation

24 of the inner screen 14. The first end 26 of the

25 base swivel 24 and thus the lower end 28 of the

26 inner screen 14 will normally remain stationary

27 since the base swivel 24 has relatively high

28 internal friction, but the minimum torque rotation

29 feature has the advantage that the first end 26 and

30 thus the lower end 28 of the inner screen 14 can

31 rotate if the electrohydraulic actuator becomes

32 stuck because, for example, sand is causing the

1 upper end 19 of the inner screen 14 to stick. This

2 feature prevents the electrohydraulic or

3 electromagnetic actuator from burning out.

4

5 Alternatively the overtorquing can be restrained by

6 frictionless bearings and the swivel, thereby

7 preventing the motor from burning out.

8

9 Returning to Figure 1a, the outer screen (not shown)

10 and the inner screen 14 are provided with an

11 interwoven lattice of outer screen shroud (not

12 shown) and inner screen shrouds 30 respectively.

13 Each shroud comprises a series of longitudinally

14 arranged bands of material, such as steel of

15 different grades selected in accordance with the

16 well conditions. The bands are coated with micro-

17 electromechanical system sensors (not shown) wherein

18 each sensor is electronically linked to a control

19 system (not shown). The respective lattice of outer

20 screen shroud (not shown) and inner screen shrouds

21 30 comprise a series of longitudinally arranged

22 bands of material 301 which are spaced apart around

23 the circumference of the respective outer 12 and

24 inner 14 screens and extend parallel to the

25 longitudinal axis of the screen system 5.

26 Additionally, the respective lattice of outer screen

27 shroud (not shown) and inner screen shrouds 30

28 comprise a series of transversely arranged rings of

29 material 30t which are spaced apart along the

30 longitudinal axis of the screen system 5 and which

31 are arranged to lie on planes perpendicular to the

32 longitudinal axis of the screen system 5.

1 Accordingly, there are a plurality of slots 32

2 provided in the interstices between the

3 longitudinally arranged bands of material 30l

4 transversely arranged rings of material 30t, where

5 the size of the slots 32 of the inner screen 14 can

6 be varied whilst the screen system 5 is in situ in

7 the well, as will be described subsequently.

8

9 Accordingly, operation of the electrohydraulic

10 actuator rotates the upper end 19 of the inner

11 screen 14 relative to the lower end 28 of the inner

12 screen 14, which results in variation of the size of

13 the plurality of slots 32 of the inner screen 14.

14

15 Figure 2 is a block diagram of the architecture of a

16 system for controlling the screen system 5. The

17 micro-electromechanical system sensors of the screen

18 system 5 are electronically linked to a measurement

19 system 40 which is in turn connectable to a

20 monitoring system 42 and an adaptive controller 44.

21 The adaptive controller 44 is also provided with

22 input data 46 relating to a desired value of a

23 measurable variable of the screen system 5. The

24 adaptive controller 44 is further connected to the

25 screen system 5 and the monitoring system 42.

26

27 Figure 3 is a flow chart of the processes occurring

28 within the screen system 5 and control system. In a

29 first step 50 well data, production data, reservoir

30 data, screen sensor data and default data are

31 entered into a computer. The well data comprises

1   details of :

2   (I)   the geometrical configuration of the well,

3   (ii)   the type of completion of the well,

4   (iii)   the designed screen O.D. and

5   (iv)   gravelpack details if the well employs

6   gravelpack completions.

7

8   The production data comprises details of the

9   production rate and flowing bottom hole pressure.

10 The reservoir data comprises details of the

11 reservoir pressure, porosity, permeability and sand

12 grain size distribution. The screen sensor data

13 comprises details of the fluid flow velocity across

14 the screen system, the pressure drop across the

15 screen system and solids concentration across the

16 screen system. The default data comprises the

17 default screen pressure drop and the default maximum

18 tolerance level for solids production.

19

20 In second step 52 the outer screen slot is pre-set

21 to a standard gauge based on Saucier rule for the

22 particular reservoir sand size distribution. In

23 other words, the outer screen shroud lattice is pre-

24 set prior to introduction of the screen system into

25 the well such that the slots or gaps 32 provided

26 between the longitudinally arranged bands of

27 material 301 and transversely arranged rings of

28 material 30t are set to the required size. In a

29 third step 54 an optimum slot size 32 is computed

30 for a given production rate and solids level. In a

31 fifth step 56 the electrohydraulic actuator is

32 instructed by the control system to rotate the inner

1   screen 14 to a desired angle in order to increase or

2   decrease the area of the slots or gaps 32 in the

3   inner screen 14 through which the fluid from the

4   well can flow. In a sixth step 58 the flow through

5   the screen system 5 and the solids loading on the

6   screen system 5 are continuously monitored by the

7   micro-electromechanical sensors and in a further

8   step 60 compared with the default maximum tolerance

9   level for solids production and the default plugging

10   pressure drop across the screen system 5 which have

11   been computed in accordance with the built in

12   classic models and entered into the computer in

13   stage 50.

14

15   Any difference between the measured variables and

16   the default values of the variables is communicated

17   to the adaptive controller which in a further step

18   62, accordingly activates the electrohydraulic

19   actuator to operate the screen system 5 to minimise

20   the difference between the measured data and the

21   default data. Thus, the electrohydraulic actuator

22   operates the screen system 5 to adjust the slot or

23   gap size 32 of the inner screen 14 in accordance

24   with the output of the adaptive controller, wherein

25   rotation in one direction, for example a clockwise

26   direction, of the upper end 19 relative to the lower

27   end 28 reduces the slot size 32 such that the area

28   through which the production fluids can flow is

29   reduced which will reduce the production fluid flow

30   rate. Conversely, rotation of the upper end 19

31   relative to the lower end 28 in the other direction,

32   for example a counter-clockwise direction, increases

1   the slot size 32 of the inner screen 14 such that

2   the area through which the production fluids can

3   flow is increased which will increase the production

4   fluid flow rate.

5

6   The adaptive controller calculates an appropriate

7   control action by way of a solids production

8   prediction model and a plugging tendency model. The

9   solids production prediction model is based upon the

10   principal that the degree of solids production or

11   migration through a downhole solids control system

12   depends upon the bridging effectiveness of the

13   control system whether the control system be

14   gravelpack or barefoot screen.

15

16   The degree of solids production or migration through

17   a downhole solids control system is a function of a

18   number of variables including:

19   1.   The formation of grain size distribution, shape

20   and density.

21   2.   The type and properties of reservoir fluid.

22   3.   The fluid production rate or injection rate

23   4.   The overall well drawdown.

24   5.   The accumulative production

25   6.   The hole angle

26   7.   The type of completion.

27

28   Accordingly the solids production is computed from

29   an established mechanistic prediction model.

30

31   Using a set of equations the maximum and minimum

32   grain size invading the screen system 5 can be

1   computed from a given bridging efficiency. The

2   maximum and minimum grain size invading the screen

3   system 5 can be employed with the solids production

4   concentration in a modified Ergun equation for

5   predicting the flow through the filtration system.

6   The plugging tendency model accounts for the effect

7   of time cumulative production and pore blocking

8   mechanisms on the flow filtration system. In the

9   plugging tendency model the plugging tendency is

10   quantified as a function of the pressure drop across

11   the screen system 5, wherein the pressure drop

12   across the screen system 5 is calculated as the sum

13   total of the pressure drop across the screen

14   aperture 32 itself and the pressure drop across the

15   solid filter cake on the screen system 5.

16

17   The invention is not limited by the examples herein-

18   beforedescribed which may be varied in construction

19   and detail. For example, an outer screen could be

20   omitted, with just an inner screen operating to

21   control the sand production -in this embodiment, the

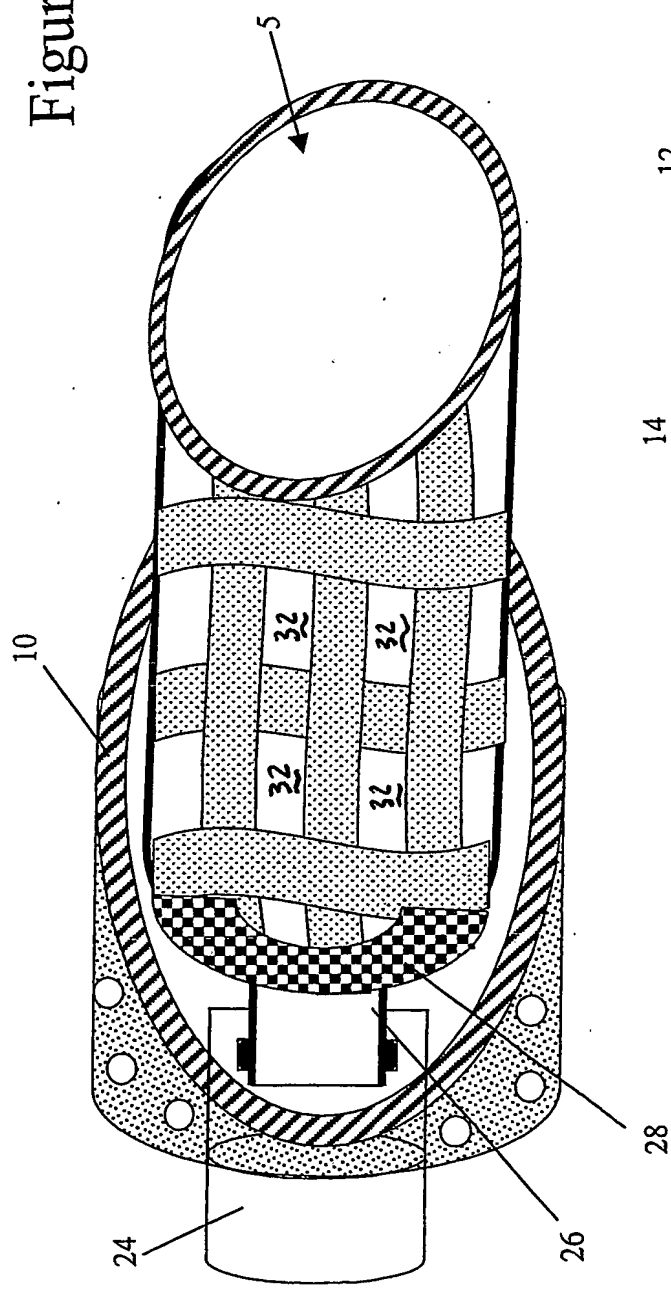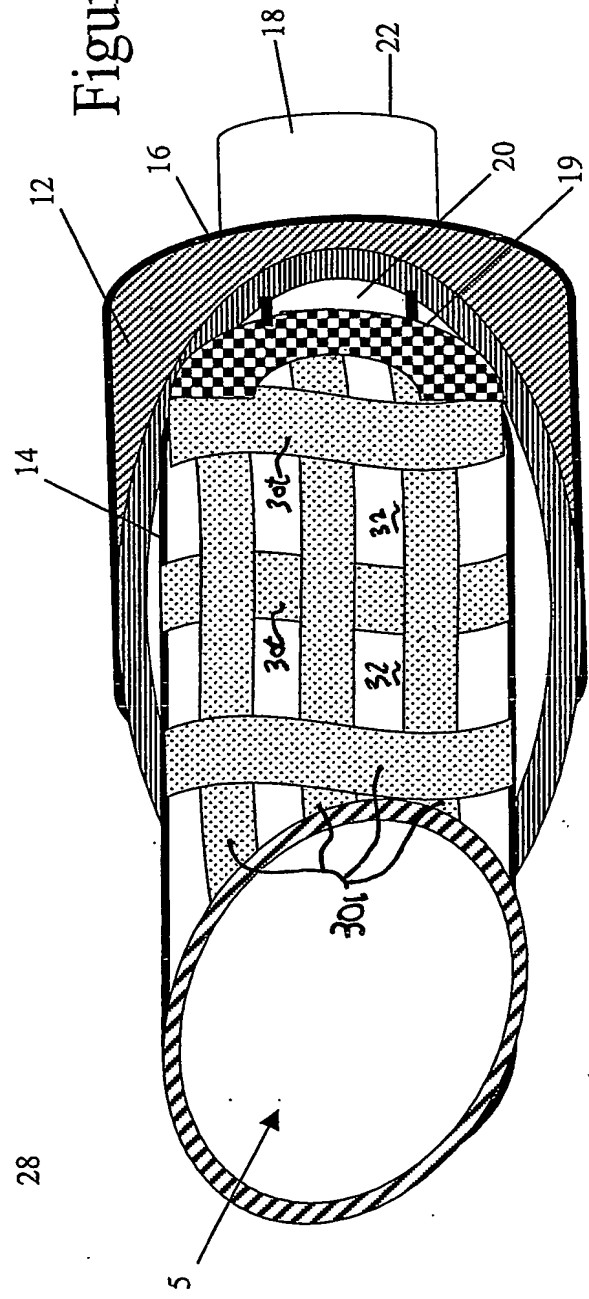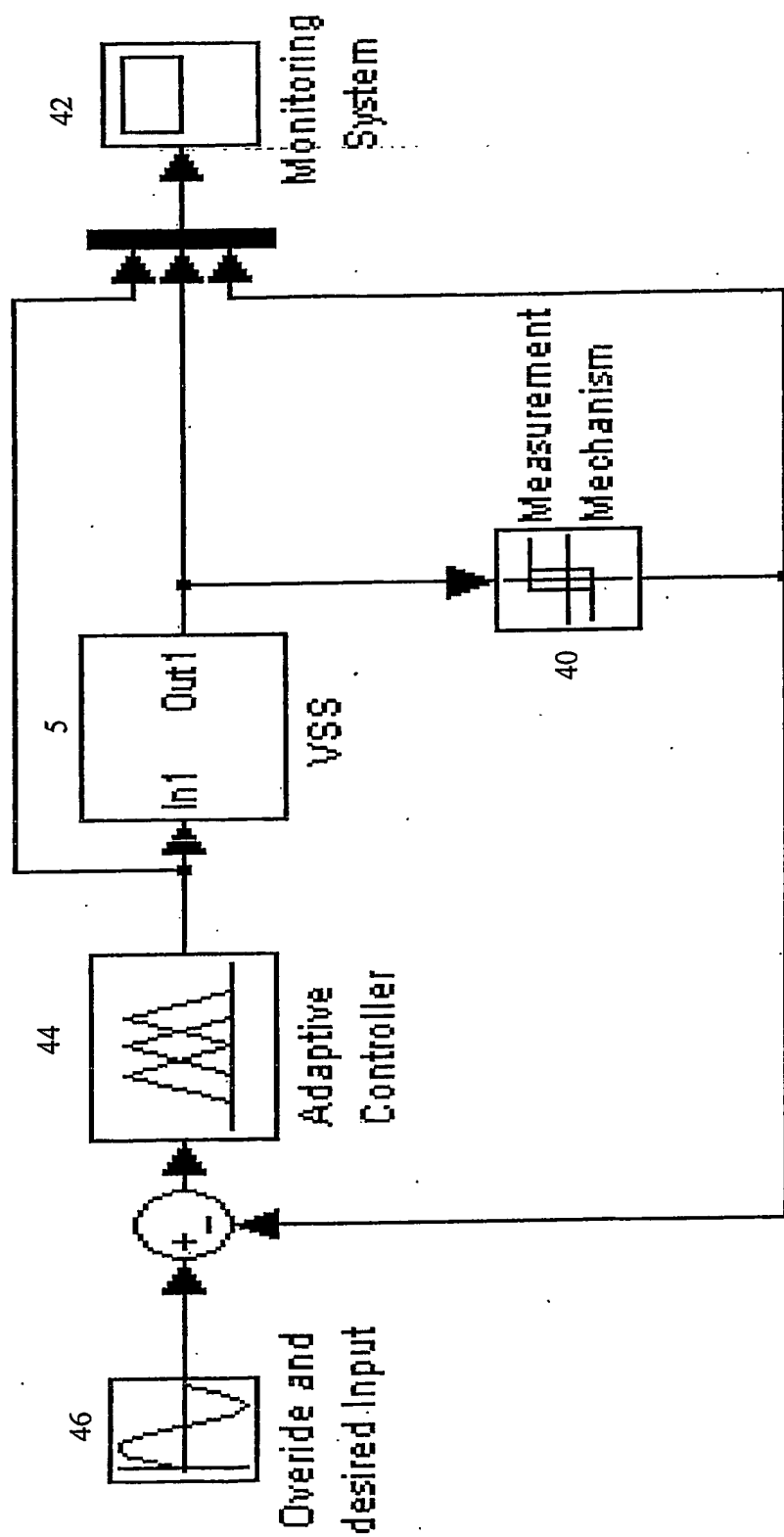22   control system would be modified accordingly.

Figure 1a

5

10

32 32

32 32

24

26

28

Figure 1b

18

22

16

12

20

19

14

30t

32

30t

32

30t

5

Figure 2

```
┌─────────────────────────────┐
│     Receive Input Data      │  50
└─────────────────────────────┘
              │
              ▼
┌─────────────────────────────┐
│    Preset Screen Slot Angle │  52
└─────────────────────────────┘
              │
              ▼
┌─────────────────────────────┐
│   Calculate Optimal Slot Size│  54
└─────────────────────────────┘
              │
              ▼
┌─────────────────────────────────────┐
│ Instruct Actuator to Adjust Inner    │  56
│ Screen Slot to Desired Angle         │
└─────────────────────────────────────┘
              │
              ▼
┌─────────────────────────────┐
│    Monitor flow and solids  │  58
│    loading by sensors       │
└─────────────────────────────┘
              │
              ▼                                    60
┌─────────────────────────────┐        ┌──────────────────────┐  62
│   Compare flow and solids   │        │   Adjust slot size   │
│  loading with default values│        └──────────────────────┘
└─────────────────────────────┘
              │
              ▼
         ╱────────────╲
        ╱  Difference  ╲
  No   ╱ between measured ╲   Yes
 ◄────┤   flow & solids    ├────►
       ╲ loading and default╱
        ╲    values ?      ╱
         ╲────────────────╱
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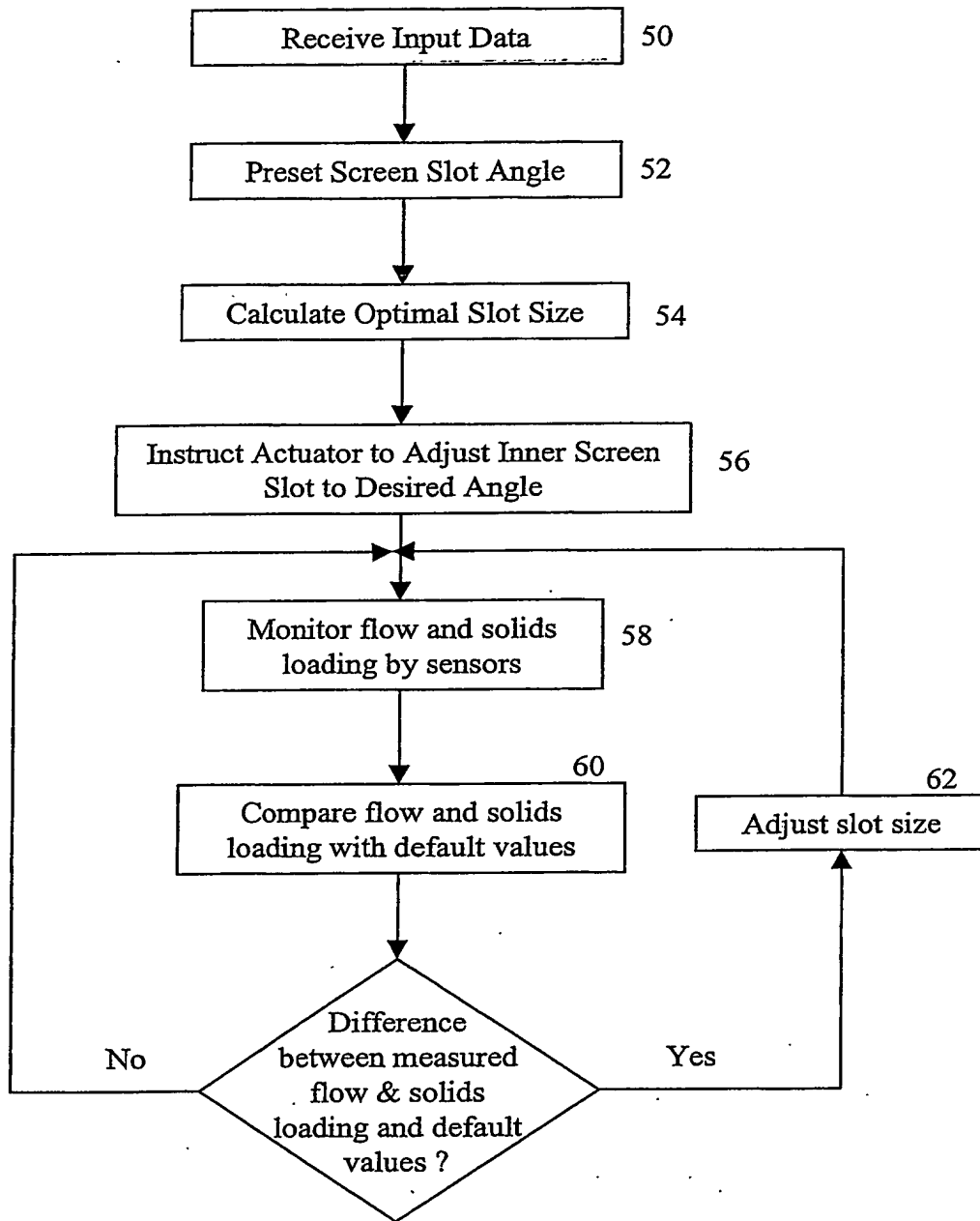
Figure 3

PCT Application
GB0303896